AMENDMENTS TO THE DRAWINGS:

The attached sheet of drawings includes changes to FIG. 4. This sheet, which includes only FIG. 4, replaces the original sheet.

Attachment: One Replacement Sheet.

REMARKS/ARGUMENTS:

Entry of the above amendments, and reconsideration and further examination of this application as amended is respectfully requested. Claims 1-22, 26, and 30-78 have been withdrawn as they are directed to a non-elected invention or non-elected species of the elected invention. Claims 23-25 and 27-29 remain in the application.

The amendments submitted above to certain paragraphs in the specification have been done so to correct informalities, such as switched, omitted, or incorrect figure reference characters or numbers, or inconsistent reference names, and to correct grammatical or spelling errors.

Specifically, the amendment made to the paragraph bridging pages 16-17 was done to correct a reference to the proper figure ("Figure 2" should be "Figure 3").

No new matter has been added through any of these amendments.

The amendments submitted above to certain claims have been done so either in response to the Examiner's rejections or objections or to correct claim dependency, to correct antecedent basis, to put the claim in conventional form, to correct punctuation, improper word usage, and the like.

No new matter has been introduced through any of these amendments.

A. Objections to the Drawings Under 37 C.F.R. § 1.83(a)

The Examiner objected to the drawings under 37 C.F.R. § 1.83(a) because the drawings must show every feature of the invention specified in the claims. In response, Applicant has amended the drawing of FIG. 4 to show the Nonconductive Spacers 45 as claimed in claim 27, and has amended the paragraph bridging pages16 and 17 describing FIG. 4 to include a description of the nonconductive spacers and their reference character "45" to conform the written specification to the claims and figures. No new matter has been added through this amendment. One replacement sheet of figures containing FIG. 4 is attached to this response in the Appendix.

B. Objections to the Specification Under 35 U.S.C. § 112, First Paragraph

The Examiner objected to the specification as failing to provide an adequate written description of the invention and as failing to adequately teach how to make and/or use the invention, i.e., failing to provide an enabling disclosure. Applicant respectfully traverses.

INTRODUCTION

The patent laws require that the applicant set forth in a patent specification sufficient information to enable a person skilled in the relevant art to make and use the invention. The "invention" that must be enabled is that defined by the particular claim or claims of the patent application.[1] An enabling *disclosure* is all that is required. The applicant need not describe actual embodiments or examples. Generally, an applicant need not include in the specification a specific working example in order to comply with the enablement requirement of Section 112.[2] The specification need only teach to one with ordinary skill in the relevant art how to make and use the invention in question. Specific examples are often included in patent specifications because examples can be the best method of teaching how to make and use the invention. Examples need not necessarily be based on actual experiments.[3]

Applicant's invention may have utility in many diverse applications, from micro-power sources to nuclear reactor sized applications. As such, any details mentioned in the various embodiments would vary greatly depending upon a specific application. The description of Applicant's invention is a generalized description that covers a broad range of sizes and applications. To describe every detail that the rejection by the Examiner implies under 35 U.S.C.

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[1] Phillips Petroleum Co. v. U.S. Steel Corp., 673 F. Supp. 1278, 6 USPQ2d 1065 (D. Del. 1987), *aff'd*, 865 F.2d 1247, 9 USPQ2d 1461 (Fed. Cir. 1989); *Ex Parte* Erlich, 3 USPQ2d 1011, 1014 (Bd. Pat. App. & Int'f 1987) ("whether the *preliminary* screening step of Example I of this or the parent application is disclosed in sufficient detail to enable one to practice that assay is not an issue that we need to decide since (1) the record is clear that one of ordinary skill in the art may screen the hybridomas produced in the present invention for monoclonal antibody production using other, well-known assays; and (2) the claims on appeal do not require the use of the assay in dispute.").

[2] Lawson v. Bruce, 222 F.2d 273, 278, 105 USPQ 440 (CCPA 1955).

[3] See, e.g. Atlas Powder Co., v. E.I. du Pont de Nemours & Co., 750 F.2d 1569, 224 USPQ 409 (Fed. Cir. 1984) (the patentee did not commit inequitable conduct be failing to inform the examiner that examples in the specification were "prophetic" rather than the results of actual tests; the specification described the examples in the present tense and the results were of actual tests modified only to reflect the most effective intended formulation).

§ 112, First Paragraph would turn the patent application into a production specification, which the rule does not require.[4]

1. Specifically, the Examiner states that "There is no adequate description nor enabling disclosure of how and in what manner the liquid semiconductor is purified or scrubbed of unwanted fission fragments as disclosed in, for example, pp 9 lines 27-30, pp 10 lines 17-18, pp 18 lines 26+ and pp 19 lines 1-7. There is also no adequate disclosure of how and in what manner a heat extractor can perform both heat extraction and semiconductor purification. The specification only discloses the desired results without providing any description of how such is accomplished hence the disclosure is insufficient and non-enabling."

Applicant's invention is directed towards a Liquid Semiconductor Nuclear Voltaic Cell (LSNVC), not a specific scrubber, system of scrubbing, heat exchanger, nor system of heat removal. The LSNVC as described in the specification is a generic, modular unit able to accept various scrubbers or heat exchangers as determined by the requirements of each particular LSNVC application and design. Scrubbers and heat exchangers are known in the art.

Additionally, scrubbing the liquid semiconductor to remove unwanted fission products is optional. The LSNVC could be a disposable design, having no provisions for scrubbing unwanted fission products. Likewise, heat removal is optional depending upon the particular application of the LSNVC. Scrubbing and heat removal could be accomplished using a variety of methods. Applicant directs the Examiner's attention to the following references related to heat removal and scrubbing:

1) Resource information on heat transfer devices based on size of the LSNVC:
    a. Computer chip size:
        Heating the LSNVC is more of a concern than heat removal.
    b. Car battery size LSNVC:
        i. Parallel-flow or counter-flow shell and tube heat exchanger:
        J.M. Coulson, J.F. Richardson, <u>Chemical Engineering: Fluid Flow, Heat</u>

[4] <u>*In re* Gay, 309 F.2d 769, 774, 135 USPQ 311, 316 (CCPA) 1962)</u> ("Obviously, it is not necessary that an applicant be more specific than is required by section 112, portion A [first paragraph]. Not every last detail is to be described, else patent specifications would turn into production specifications, which they were never intended to be. United States specifications have often been criticized as too cluttered with details to give an easy understanding of what the invention really is.").

Transfer and Mass Transfer, Vol. 1, Part 2, Butterworth and Heinemann, Oxford, 1999.

ii. Separate fluid heat exchanger:

Y.A. Cengel, Heat Transfer: A Practical Approach, Chapter 10, McGraw-Hill, Boston, 1998.

iii. Liquid Semiconductor flow heat removal:

A combination of the previous two references could be utilized.

c. Reactor size LSNVC:

i. Separate fluid cooling system:

1) J.R. Lamarsh, Introduction to Nuclear Engineering, 3rd Edition, Chapter 8, Addison-Wesley publishing Company, London, 2001.

ii. Liquid Semiconductor flow heat removal:

1) same as 1.b.ii-iii.

Other references:

With reactor size LSNVS you have to consider the effects of the heat on the criticality of the core when designing cooling systems.

1) W.M. Stacey., Nuclear Reactor Physics, pp. 267-268, John Wiley & Sons, Inc., New York, 2001.

2) Resource information on scrubbers:

a. Pyrochemical Separation Methods:

i. "Innovative Technologies for Nuclear Fuel Cycles and Nuclear Power," International Conference held in Vienna, International Atomic Energy Agency (IAEA), Electric Utility Cost Group Inc., International Science and Technology Centre, and World Nuclear Association, 2003.

ii. V.A. Volkovicha, et al., "Treatment of molten salt wastes by phosphate precipitation: removal of fission product elements after pyrochemical reprocessing of spent nuclear fuels in chloride melts," Journal of Nuclear Materials, Volume 323, Issue1, November 15, pp 49-56, 2003. http://www.rcgg.ufrgs.br/InproConf-2003.pdf

iii. V.A. Volkovicha, et al., "Behavior of molybdenum in pyrochemical reprocessing: A spectroscopic study of the chlorination of molybdenum

and its oxides in chloride melts," Journal of Nuclear Materials, Volume 323, Issue 1, pp 93-100. November 15, 2003.

iv. T. Usami, et al., "Pyrochemical reduction of uranium dioxide and plutonium dioxide by lithium metal," Journal of Nuclear Materials, Volume 300, Issue 1, pp 15-26, January 2002.

v. J.M. Haschke, et al., "Analysis and characterization of plutonium in pyrochemical salt residues," Journal of Nuclear Materials, Volume 277, Issues 2-3, pp 175-183, February 2000.

vi. D.M. Smith, et al., "Plutonium pyrochemical salts oxidation and distillation processing: Residue stabilization and fundamental studies," American Institute of Physics (AIP) Conference Proceedings, Volume 532, Issue 1, pp 238-328, July 2000.

b. Electrometallurgical Methods:

i. Koyama, T. et al., "Integrated Experiments to Demonstrate Innovative Reprocessing of Metal and Oxide Fuel By Means of Electrometallurgical Technology," International Conference held in Vienna, International Atomic Energy Agency (IAEA), 2003.

c. Li Reduction and Electrorefining Method:

i. Tokiwai, M., et al., "Development of metallic uranium recovery technology from uranium oxide by Li reduction and electrorefining," ibid, p 917.

d. General methods

i. Koma, Y., et al., "Separation Process of Long-Lived Radionuclides for Advanced Fuel Recycling," Global 2001, Paris, France (Sep. 2001)

ii. Kurata, M., et al., "Conversion of high level waste to chloride for pyrometallurgical partitioning of minor actinides," Proceedings of 7th Int. Conf. On Radioactive Waste Management and Environmental Remediation, ICEM '99, Nagoya, 26-30 September, 1999.

iii. Fujii, K., et al., "Effects of Separation of Minor Actinide, Cesium and Strontium on High-level Radioactive Waste Disposal," Proc. of the RRTD 2nd International Workshop on Nuclear Fuel Cycle –Nuclear Fuel Cycle

from the Viewpoint of Disposal Site Utilization, Aomori, Japan (Mar. 2003).

Scrubbing could be accomplished with the pyrochemical separation method, electrometallurgical method, Li reduction and electrorefining method, etc. Heat removal could be done with heat sinks, parallel-flow or counter-flow shell and tube heat exchangers, separate fluid cooling systems, etc. The LSNVC could incorporate these two features, but the details of scrubbing and heat removal are not the invention, are known in the art, and are dependent entirely on the specific application of the LSNVC.

The following are just a few examples:

1. A small LSNVC that uses no heat exchanger at all.
2. A small LSNVC that uses a simple aluminum heat sink as a heat exchanger.
3. A larger LSNVC that uses the liquid semiconductor as the working fluid in a counter-flow heat exchanger.
4. A large LSNVC that uses a dedicated cooling loop with a different working fluid.

The selection of the heat exchanger, if any, will depend entirely upon the anticipated application of the LSNVC. Going a step beyond that, research, experimentation and optimization would ultimately determine the best choice out of many acceptable choices for selecting a heat exchanger for a particular application.

2. The Examiner states that "There is no adequate description nor enabling disclosure of how and in what manner fissile material may be added intermittently to replace the fissile material burned up in the fission process as disclosed in, for example, pp 9 lines 30+, pp 10 line 18 and pp 19 lines 4-7. There is also no adequate disclosure of how and in what manner a heat extractor can perform both heat extraction and fissile material replacement. The specification only discloses the desired results without providing any description of how such is accomplished hence the disclosure is insufficient and nonenabling."

Applicant's invention is directed towards a Liquid Semiconductor Nuclear Voltaic Cell (LSNVC). The LSNVC as described in the specification is a generic, modular unit able to accept different devices or means of adding new fissile or non-fissile radioactive material as determined

by the requirements of a particular design. If the material is in solution, then it may be mechanically administered and mixed into the liquid semiconductor. The form of the material will determine how it is administered. A liquid or powder could be injected into the liquid semiconductor, while a metal (like uranium) would have to first be raked into smaller fragments for quicker dissolution in the liquid semiconductor.

The addition of new fissile material to replace burned-up fissile material is optional. The LSNVC could be a disposable design, having no provisions for replenishing burned up fissile material. Ideally the LSNVC could incorporate a feature or device to accommodate the addition of fissile material. But the details of such a device are not the invention, are known in the art, and are dependent entirely on the specific application of the LSNVC.

For example, a heat exchanger/cooling loop may be designed to accomplish cooling, scrubbing, and addition of new fissile material. As it leaves the core, the liquid semiconductor could be cooled to just above the melt temperature by an external cooling loop, then run through a scrubbing cycle (this could be done before the cooling if the elevated temperature was advantageous to the process), and finally small traces of fissile material could be mechanically administered. However, the specifics of this arrangement would vary widely depending upon the particular application and design of the LSNVC.

3. The Examiner states that "There is no adequate description nor enabling disclosure of how and in what manner the cooling loop is maintained in a liquid form. It is not seen wherein the specification takes into account the thermal losses inherent in transporting the hot semiconductor liquid from the reaction site to the cooler and back, hence the disclosure is insufficient and nonenabling."

Applicant's invention is directed towards a Liquid Semiconductor Nuclear Voltaic Cell. The LSNVC as described in the specification is a generic, modular unit able to accept various heat exchangers as determined by the requirements of the particular design. Smaller systems would not require cooling. Instead they would be focused on maintaining the ideal heated temperature. In a larger system, the liquid semiconductor may not be the method of cooling the core. Instead, heat may be extracted by external or internal cooling pipes (heat exchangers), where most of the heat is transferred by conduction to the coolant. The use of the liquid

semiconductor as the coolant depends on the flow rate, how hot the LSNVC gets, and the complexity of scrubbing and refueling. In cases where loss of temperature in fluid transport is not advantageous, insulation could easily be applied.

A heat exchanger is an optional feature depending upon the specific application of the LSNVC. Maintaining the semiconductor in a liquid state during the cooling stage would be imperative for the correct operation of a heat exchanger, if a heat exchanger were to be used. However, designing a heat exchanger to accomplish cooling while maintaining the semiconductor in liquid form depends entirely on the size of the device, the type of heat exchanger chosen, the materials used in the LSNVC, the liquid semiconductor chosen, the flow rate, and other variables. The details for specific heat exchangers is not the invention, are known in the art, and are dependent entirely on the specific application of the LSNVC.

4. The Examiner states that "There is no adequate description nor enabling disclosure of how and in what manner the nuclear voltaic cell is heated so as to melt the liquid semiconductor as disclosed in, for example, pp 14 lines 1-11. There is no disclosure of how an external heating source is to be incorporated with the cell in order to melt said semiconductor or how such is accomplished, hence the disclosure is insufficient and non enabling."

Applicant's invention is directed towards a Liquid Semiconductor Nuclear Voltaic Cell. The LSNVC as described in the specification is a generic, modular unit able to accept various heaters to melt the semiconductor as determined by the requirements of a particular design. The selection of a heater would depend totally upon the configuration and application of the LSNVC in question. Variables to consider in the selection of a heater include size of the LSNVC, material selection, semiconductor selection, time to melt, etc. The selection of a specific heater for a generalized system does not make sense. A reactor size LSNVC may not even require a heater. Instead they may use a warm-up period after having its core fission production rate raised to the operation level. Examples of heaters that could possibly be suitable include hot plates (smaller LSNVC systems), heating coils, and heating elements (rods).

5. The Examiner states that "There is no adequate description nor enabling disclosure of how and in what manner 'persons familiar with the art' are to select the materials of construction of the entire invention in order to operate as disclosed. Applicant again has stated the desired

results of the materials to be selected, for example, pp 13 lines 12-17, 'As persons familiar with the art will understand, the Ohmic Contact 10 is preferably made from a metal such that no, or a minimal barrier exists between the Ohmic Contact 10 and the Liquid Semiconductor 20. Furthermore, as persons familiar with the art will understand, the Schottky Contact 30 is preferably made from a metal such that when placed in contact with the Liquid Semiconductor 20 a substantial electrostatic barrier is created across the liquid', however it is not seen wherein specific examples of materials that accomplish the desired effect are disclosed. It is not seen wherein specific materials that are compatible with each other so as to present an operative embodiment are disclosed, hence the disclosure is insufficient and nonenabling."

A person familiar with the art would be able to make materials selection based on the particular application of the LSNVC. Work functions being understood, the other parameters include: neutronics, melting point, corrosion, and chemical reactiveness with the liquid semiconductor material.

For example, for a reactor core application of the LSNVC, the scientist has to consider sustaining the fission reaction. Therefore, all the material has to have lower neutron interaction cross-section, so a material like cadmium would clearly be a poor choice. In smaller sub-critical systems, such as a "battery" type application, this would not be a concern. A "battery" type design would direct one skilled in the art to focus more on issues such as the chemical boundary interfaces.

6. The Examiner states that "There is no adequate description nor enabling disclosure of the overall dimensions of the invention. Page 13 lines 22-25 disclose that the cross section of the strata making up the active parts of the invention are .0163 cm however it is not seen where other dimensions are disclosed to present an operative embodiment. There is also no adequate description of how and in what manner the device can be scaled up to the systems disclosed in, for example figures 9-11 including exactly how and in what manner the liquid semiconductor can be forced to flow through the nuclear voltaic cells in a useful manner."

Applicant's invention is directed towards a Liquid Semiconductor Nuclear Voltaic Cell (LSNVC). The LSNVC as described in the specification is a generic, modular unit that will vary in size depending upon the specific application. Choice of liquid semiconductor and whether or

not it recycles the fluid play major roles in the system dimensions. In a flowing regime, a liquid with higher viscosity would require a larger channel width and/or larger pressure gradient. The channel width is also dependent on the electron-hole collection efficiency of the semiconductor material.

For example, a small LSNVC may be designed to fit onto a circuit board. A large array of LSNVCs may be combined to the size of a typical reactor core. In addition to the dimensions shown in FIG. 1, FIG. 8 provides various dimensions for multiple LSNVCs connected into an array. Applicant believes that these dimensions disclosed are more than adequate for the enablement requirement. Pumps of various types and sizes may be used to force the liquid semiconductor to flow. Any pump that produces a uniform pressure gradient could work. The flow rate would depend on the life time of the liquid semiconductor in the harsh nuclear environment.

C. Rejection of Claims <u>Under 35 U.S.C. § 112, First Paragraph</u>

The Examiner rejected claims 23-25 and 27-29 under 35 U.S.C. §112, first paragraph for failing to comply with the enablement requirement. Applicant respectfully traverses. Applicant incorporates herein the arguments made above in Section B. In addition, Applicant has amended "metallic contact layer" throughout the claims to read "metal contact layer" which finds support throughout the specification. See, for example, page 8, lines 7-9 and lines 19-22; page 8, line 31 through page 9, line 3; page 9, lines 11-14; page 11, lines 1-4 and lines 13-15; page 12, lines 25-28; and page 13, lines 1-7 and FIGS. 1-7. Applicant also makes reference to "metallic contacts" on page 8, lines 10-13, but most frequently Applicant refers to "metal contacts." No distinction is made by Applicant between the terms "metallic contacts" and "metal contacts." Thus, Applicant believes that claims 23-25 and 27-29 overcome the Examiner's rejection thereof under 35 U.S.C. §112, first paragraph, and reconsideration of that rejection is respectfully requested.

D. Rejection of Claims <u>Under 35 U.S.C. § 112, Second Paragraph</u>

The Examiner rejected claims 23-25 and 27-29 under 35 U.S.C. §112, second paragraph as being indefinite for failing to particularly point out and distinctly claim the subject matter

which applicant regards as the invention. In response to the above rejection, Applicant has amended claims 23, 24, 27, 28, and 29 to address the issues raised by the Examiner.

Specifically, Applicant has attempted to resolve all antecedent basis problems pointed out by the Examiner, as well as other instances found by Applicant.

Applicant has amended claim 23 to indicate that the liquid semiconductor contacts the two metal contact layers. Applicant has also amended claim 23 to clarify the relationship between the two metal contact layers, identifying a first side for each metal contact layer, and that these two first sides are positioned to face each other, forming a channel there between. Support for this amendment may be found on page 13, lines 14-17; page 14, lines 16-21; page 16, lines 28-31; and in reference to FIGS. 1-6.

Applicant believes that claim 25 as submitted is in proper form and not in need of amending.

Applicant has amended claim 27 to indicate that, in addition to the liquid semiconductor contacting the two metal contact layers, the liquid semiconductor surrounds the nonconductive spacers. Applicant has also amended claim 27 in conjunction with amended FIG. 4 and the amended paragraph bridging pages 16 and 17 to clarify the relationship of the nonconductive spacers to the two metal contact layers, and that the nonconductive spacers maintain the channel separating the metal contact layers. Support for these amendments may be found on page 13, lines 24-25; page 16, line 28 through page 17, line 5 (as amended); and FIG. 4 (as amended).

Applicant has amended claim 28 to clarify the flow of the liquid semiconductor through the channel formed by the two metal contact layers. Support for this amendment may be found on page 13, lines 1-11 and in reference to FIG. 1 (arrows 15 and 25).

Applicant has amended claim 29 to clarify the mandrel used to form a cell by wrapping the two metal contact layers around it. Support for this amendment may be found on page 8, lines 14-16; page 9, lines 7-8; page 11, lines 8-9; page 17, lines 14-23 and in reference to FIG. 7.

As a result, Applicant believes that claims 23-25 and 27-29, as amended, overcome the Examiner's rejection thereof under 35 U.S.C. §112, second paragraph, and reconsideration of that rejection is respectfully requested.

E. Rejection of Claims
Under 35 U.S.C. § 103(a)

1. The Examiner has rejected claims 23-25, 27, and 28 under 35 U.S.C. §103(a) as being unpatentable over Brown, U.S. Patent No. 6,118,204 in view either of Denninger or Kherani et al., U.S. Patent No. 5,606,213, and further in view of any of Little et al., U.S. Patent No. 5,260,621, Godlevsky et al., Yu et al., Kulkarni et al., Price et al., Matthiesen et al., or Enderby et al.

Applicant respectfully traverses. There are two avenues of approach for an investigator to realize Applicant's invention. First, a scientist in the study of liquid semiconductors could discover the energy harvesting potential of his material combined with fissile material. Second, a scientist in the study of direct energy conversion could conclude that many of the problems associated with semiconductors could be solved in liquid forms. The question is whether either approach would be obvious to a person of ordinary skill in that art.

Liquid Semiconductor Approach

To examine the first approach an understanding of the goals and mindsets of the liquid semiconductor scientists is needed. Researchers in this field are primarily focused on the development of the science and/or finding a commercial outlet for their ideas. Scientists will look for current semiconductor applications and endeavor to show how much better the liquid form could be. The potential applications of liquid semiconductor are numerous. Though developed with amorphous solid-state semiconductors, Xerox's patents for scanners and DuPont's (now Sterling Diagnostic Imaging) patents on x-ray devices are two examples of the direction that liquid semiconductor scientists will most likely follow.

As far as the general researcher understands, semiconductors are not currently being used to collect large amounts of energy from a nuclear source for power generation. If semiconductors in general are not being used in this way, it is not obvious to one skilled in the

art to use liquid semiconductors in this way either. This is illustrated further below in the discussion of the prior art cited by the Examiner.

Regarding liquid semiconductors, the bulk of the recent work has primarily focused on the photosensitive aspects of the material or simply its electrical and physical attributes in different states and/or forms. Applicant is not aware of any studies on the nuclear effects on liquid semiconductors. The liquid semiconductor scientist's interests do not seem to be in line with a power production regime. Applicant can find no mention in the literature of the use of liquid semiconductors in the collection of power from a nuclear source.

In examining the prior art cited by the Examiner, it can be seen that the mindset of the scientist in the liquid semiconductor field is not focused on direct energy conversion. Additionally, few of the references seem to lend any serious information that would be of much value to a direct energy conversion investigator.

Yu et al. teaches the molecular dynamics of the surface tension and surface profile of liquid Si and Ge. This is simply a material study of liquid semiconductors with no mention of the electrical, photosensitive, or nuclear properties of the materials.

Godlevsky et al. reports the behavior difference between the silicon group and the chalcogen group in liquid forms. The former loses its semiconductor properties and behaves more as a metal, while the latter retains its semiconductor properties. The study focus is on the electrical properties of two types of materials in different states. No attention is given or suggested as to the photosensitive or nuclear aspects of the materials.

Price et al. reports on the semiconductor properties of lead and tin mixed with heavy alkali metals. This study examines the physical "lattice" structure of the material in both solid and liquid state. The study also covers the electrical effects of material in its different states. Price et al. employs quasi-elastic neutron scattering (QENS) to determine the nature of disorder in the material studied, but does not use neutrons as a means of power collection (which would not be a good particle for power collection anyway). No mention is made of the photosensitive or nuclear aspects of the material.

Enderby et al. provides a good overview of the electronic and structural properties of semiconductors in the liquid form. The paper covers several potential liquid semiconductors to include the chalcogen group. Still, this study is focused on the chemical, structural, and electronic properties. Again, no mention is made either of the photosensitive properties or the nuclear properties of these materials.

Thus, the prior art cited by the Examiner regarding liquid semiconductors does not mention or suggest any nuclear power configurations. The papers are focused on the more general scientific studies, and in a few cases, to electrical circuit usage. The researchers are looking for new evidence on the advantages of liquid semiconductors in the solid-state world. The developers are looking for new applications of liquid semiconductors in the realm of electronics, hopefully with a quick return on investment. Neither focus recognizes or contemplates the potential use of liquid semiconductors in direct energy conversion.

Direct Energy Conversion Approach

Regarding the second approach, direct energy conversion was considered at the very beginning of nuclear reactor development. Smaller sub-critical power systems, like the nuclear batteries of Kherani et al. and Little et al., were also studied. It was concluded long ago that direct energy conversion was not practical due to several factors. The most notable were that the crystalline structure of the semiconductor (1) could not survive the hostile environment of a reactor core, and (2) would degrade rapidly in a battery configuration. Serious interest in this method of energy harvesting was quickly lost to the thermal cycle methods.

Scientists have been familiar with liquid semiconductors for over forty years, yet until Applicant's invention, it has never occurred to anyone to use liquid semiconductors for direct energy conversion. Applicant is not aware of any published breakthroughs on nuclear energy collection utilizing liquid semiconductors. This long gap in time strongly indicates that their use is not obvious. The reasons why are made more clear in the following section.

For an investigator in direct energy conversion it is not an obvious choice to use liquid semiconductors. The volume of information a nuclear scientist can draw upon for power collection overwhelming supports solid-state crystalline structures. There is little known about

liquid semiconductors especially when considering its applications with particle radiation. Brown is one of the earliest, though not the first, to recognize the use of amorphous semiconductor materials (semiconductor material that has only short-range order and is therefore only partially crystalline) in power collection. This was a bold step away from the traditional to a more obscure (but promising) field of study. If going from solid-state crystalline structures to amorphous semiconductor materials was a bold step, Applicant's use of liquid semiconductor material can only be categorized as a huge leap. Brown does not disclose liquid semiconductors, nor does Brown suggest or motivate one skilled in the art to use liquid semiconductors.

Applicant's invention which utilizes liquid semiconductors as the medium for nuclear power collection is indeed a huge leap in a more dramatic direction than that taken by Brown. Liquid and amorphous solid-state semiconductor sciences have similar concepts behind them, but the liquid form steps away from the structure stability of amorphous solid-state semiconductors and introduces many complications. Research used for amorphous solid-state semiconductors can be considered when doing research for liquid semiconductors. Yet, when working with a liquid form, there are many additional variables that need to be determined.

Though the use of amorphous solid-state semiconductors does solve some of the issues with direct conversion of energy, it still has many shortcomings. Uses of amorphous solid-state semiconductors partially solve the cell deterioration problems in batteries. However, its annealing behavior is not strong enough to survive within a nuclear reactor environment. Also, inside the cells the impurities will migrate to the surface due to the applied or natural electric field. The chemical effects at the boundaries will also help facilitate the migration. The Yu et al. article does offer possibilities of choosing impurities with lower surface tension to get the migration to shift towards the center. Yet, the choice of doping material is more dependent on its effects on electron-hole mobility. This selection may not work in favor of low surface tension. Amorphous solid-state semiconductors also do not address refueling and maintaining doping percentage issues.

Applicant has resolved these problems with the use of liquid semiconductors. They can have a faster annealing rate and a flow can be applied to allow for the refueling and correction of the doping levels with the material. Also, with the higher temperatures expected within a reactor

core, it is more practical to work with the semiconductor in liquid form considering the lower melting points of the material.

The use of liquid semiconductors however has many complications associated with it. As illustrated in the pervious liquid semiconductor section, the studies do not offer much information relevant to direct energy conversion investigators. Before a direct energy conversion scientist can seriously consider the concept behind Applicant's invention, they must first begin to research into the chemical, physical, and nuclear properties of the liquid semiconductors. Many of the variables a liquid semiconductor scientist develops in his experiments shift or change when factoring in the neutronics and stopping power of a material. For example, densities now become a much more complex issue. Most solid materials become less dense when in liquid form, particularly materials that retain semiconductor properties (like the chalcogens). Thus, Brown teaches away from liquid semiconductors because Brown espouses higher density for more efficient energy capture (col. 10, lines 51-54). If we consider all the factors that affect efficiency, density is not a primary concern. However, density can favor the nuclear considerations depending on the system configuration. The inter-dependencies of all the variables are quite complex.

In a reactor design, the semiconductor material in the cell has to have low cross-section for neutrons, and yet still have all the many good electrical properties, and a lower melt temperature and viscosity. It would also be nice to find a rare material that is denser in liquid form, but it may not help (or could possibly even hurt) the other aspects of the device. Pure germanium, for example, loses its semiconductor properties at higher temperatures, particularly after melt.

One of the key issues with liquids is the lack of mechanical stability in the diode. After the semiconductor material heats up to its melt temp, the Schottky material sputtered on top begins to "bow" downward, potentially causing the diode to short. Applicant's invention solves this problem with the use of non-conductive spacers. Brown refers to the use of krypton-85 as a radioisotope, not as a spacer (col. 8, lines 52-55). Krypton gas does not contribute to the mechanical stability of the diode. Brown is using solid-state amorphous material and is satisfied with the mechanical structure of his system (col. 10, line 12-15). Brown has no need for

mechanical structural support that the non-conductive spacers provide in Applicant's invention. Thus, Brown again teaches away from Applicant's invention.

In the power scheme, it is best to keep the diode material in a semiconductor state. Increased conductivity is good to a point, and then losses due to low resistance across the semiconductor adversely affect the power collection. Most materials lose their semiconductor properties at higher temperatures and shift to a more metallic state. This is one of the appeals of the chalcogens. They do not lose their semiconductor properties till well past the melting point.

In direct energy conversion, it is not an obvious choice to a person of ordinary skill in the art to use liquid semiconductors to harvest nuclear energy directly, and more particularly, in the fashion of Applicant's invention. The prior art cited by the examiner in the field of liquid semiconductors contains no evidence of anyone suggesting liquid semiconductor use for harvesting nuclear energy. Likewise, in the field of direct energy conversion, the prior art cited by the examiner does not suggest to one skilled in the art the use of liquid semiconductors. Brown discloses the use of amorphous semiconductor material for direct energy conversion, but there is no suggestion in Brown to use liquid semiconductors.

The liquid semiconductor and direct energy conversion sciences are the only two approaches an investigator could reasonably take to discover Applicant's invention. However, the studies in liquid semiconductors are not focused to answer most of the questions that a direct energy conversion researcher would seek to have answered. They are mostly interested in pure scientific or academic pursuits, or to improve applications in the current semiconductor sciences. This leaves the nuclear scientists with little to consider when choosing a semiconductor for his device. The more clever could consider the amorphous state, but it is not obvious that anyone of ordinary skill in the nuclear art would consider the use of a liquid instead of a solid. They are more likely to be interested in a self-healing solid than a self-healing liquid.

In summary, Brown does not disclose liquid semiconductors, nor does Brown suggest or motivate one skilled in the art to use liquid semiconductors over amorphous semiconductor material. Brown teaches away from liquid semiconductors because Brown espouses higher density for more efficient energy capture (col. 10, lines 51-54), and most solid materials become less dense when in liquid form. Brown has no need for the mechanical structural support that the

non-conductive spacers provide in Applicant's invention. Thus, Brown again teaches away from Applicant's invention. There is no suggestion in Brown, or in view of the other prior art cited by the examiner, to combine the teaching of Brown with the teachings of Denninger, Kherani et al., Little et al., Godlevsky et al., Yu et al., Kulkarni et al., Price et al., Matthiesen et al., or Enderby et al. to arrive at Applicant's invention. There is no suggestion in the prior art focused on the study of liquid semiconductors to use liquid semiconductors for direct energy conversion purposes. There is no suggestion in the prior art focused on the study of direct energy conversion to substitute liquid semiconductors for solid-state crystalline structures for power collection. Thus, Applicant believes that independent claim 23, as amended, is patentable over Brown in view either of Denninger or Kherani et al., and further in view of any of Little et al., Godlevsky et al., Yu et al., Kulkarni et al., Price et al., Matthiesen et al., or Enderby et al. and withdrawal of the rejection under 35 U.S.C. §103(a) in respect to this claim is respectfully requested.

Claims 24, 25, 27 and 28, through dependency, embody all the elements and limitations of independent claim 23. As argued above, Applicant believes that Brown in view either of Denninger or Kherani et al., and further in view of any of Little et al., Godlevsky et al., Yu et al., Kulkarni et al., Price et al., Matthiesen et al., or Enderby et al. does not render claim 23 obvious. Thus, Applicant believes that dependent claims 24, 25, 27 and 28 are also patentable over Brown in view either of Denninger or Kherani et al., and further in view of any of Little et al., Godlevsky et al., Yu et al., Kulkarni et al., Price et al., Matthiesen et al., or Enderby et al. Accordingly, Applicant requests retraction of the Examiner's rejection of these claims under 35 U.S.C. §103(a).

2. The Examiner has rejected claim 29 under 35 U.S.C. §103(a) as being unpatentable over Brown, U.S. Patent No. 6,118,204 in view either of Denninger or Kherani et al., U.S. Patent No. 5,606,213, and further in view of any of Little et al., U.S. Patent No. 5,260,621, Godlevsky et al., Yu et al., Kulkarni et al., Price et al., Matthiesen et al., or Enderby et al. and further in view of Knight, U.S. Patent No. 3,344,289.

Applicant respectfully traverses. Applicant repeats the arguments made above in section E(1) in relation to claims 23-25, 27, and 28. In view of the above arguments, Applicant believes

that independent claim 23 is patentable over Brown in view either of Denninger or Kherani et al., and further in view of any of Little et al., Godlevsky et al., Yu et al., Kulkarni et al., Price et al., Matthiesen et al., or Enderby et al. Claim 29, through dependency, embodies all the elements and limitations of independent claim 23. Thus, Applicant believes that dependent claims 29 is also patentable over Brown in view either of Denninger or Kherani et al., and further in view of any of Little et al., Godlevsky et al., Yu et al., Kulkarni et al., Price et al., Matthiesen et al., or Enderby et al. and further in view of Knight. Accordingly, Applicant requests retraction of the Examiner's rejection of this claim under 35 U.S.C. §103(a).

CONCLUSION:

A bona-fide attempt has been made to place this application in condition for allowance. Each of the Examiner's bases for objection and/or rejection have been addressed and the claims have been amended, canceled, or arguments presented to overcome such objections and/or rejections. The application is now believed to meet all statutory requirements and is thus believed to be in condition for allowance. The Examiner's early indication to that effect is, therefore, courteously solicited.

If a telephone conference would expedite allowance or resolve any additional questions, such a call is invited at the Examiner's convenience.

If any fees are due with this response, please charge any fees due, or credit any overpayment to, deposit account 13-2725.

Respectfully submitted,

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Date: March 22, 2006

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APPENDIX

One Replacement Sheet Of Drawings